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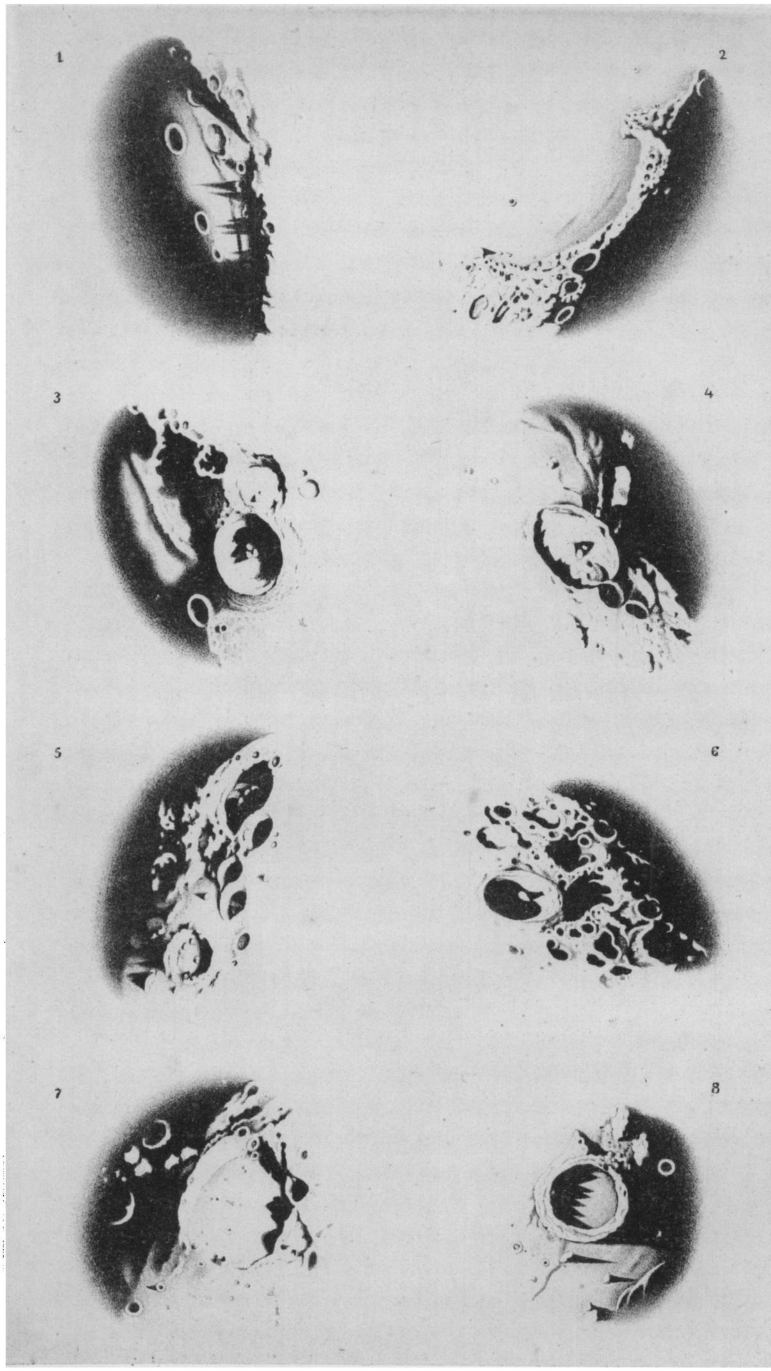

Drawings of the Moon, by Professor Weinek.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. II. SAN FRANCISCO, CALIFORNIA, SEPTEMBER 13, 1890. No. 10.

DRAWINGS OF THE MOON.*

BY PROF. DR. L. WEINEK, DIRECTOR OF THE IMPERIAL OBSERVATORY AT PRAGUE.

When, by the invention of the telescope, the eye of the astronomer was sharpened to an undreamed-of extent, and the most wonderful mountain sceneries, with constantly changing shadows, were discovered on the moon, our nearest celestial neighbor, several observers immediately undertook to make drawings of what they saw, partly to advance the knowledge which we had of our satellite and its singular surface formations, and partly to lay a foundation, for future generations, for the solution of the question whether any changes take place on the moon which can be detected by the inhabitants of the earth. It is obvious that the production of such maps, with their rich detail, requires equal perseverance and ability, and we cannot fail to admire the courage of the gifted men who devoted themselves to the solution of this extensive and difficult task.

Among the most important selenographers of the seventeenth century we must mention HEVELIUS, proprietor of a brewery in Danzig and mayor of the city, who gained great renown by his work "*Selenographia sive Lunæ Descriptio*," which was published in 1647 in folio. His work is founded on observations of the moon made during a period of five years, through telescopes of six and eight feet focus (instruments of his own construction), with a magnifying power of thirty to forty diameters, and contains, in addition to forty pictures of the different phases of the moon, comprising the period of a whole lunation, three maps of the full moon, of which the largest has a diameter of 28.5 centimeters (11.22 inches). All of these plates were not only drawn, but even engraved on copper, by HEVELIUS personally.

The principal plate of the moon shows the crater formations,

* English translation by Mr. F. R. ZIEL.

throwing short shadows towards the west, the shading being by lines, either wide or near together, so as to give the proper character to the dark or light portions of the disc. Although this map was based on only approximate positions, it remained the best one in existence for over one hundred years.

In the middle of the eighteenth century TOBIAS MAYER, of Goettingen, Professor of Agriculture and Mathematics, created a new and fundamental epoch in the study of the surface of the moon, by exact measurements of twenty-four lunar objects, and by adding to these some sixty-three points whose positions were very approximately established. After reducing these measurements to *mean* libration, he obtained a chart of the moon, with a diameter of 20.3 centimeters (7.99 inches). This chart was not published till after his death (1762), in the year 1775. It was superior to the one made by HEVELIUS in correctness and finish, and ranked as the best map of the moon until the year 1824.

By the aid of MAYER's rich collection of drawings, KLINKERFUES published—in the year 1881—a map of the full moon, having a diameter of 35 centimeters (13.78 inches), with numerous pictures of special regions, under the title "TOBIAS MAYER's *groessere Mondkarte nebst Detailzeichnungen*," in which all objects are represented as throwing shadows towards the east. The photo-lithographic reproduction shows the skill of the maker, although he was unable to devote himself to very minute details, having undertaken too extensive tasks for the single nights of observation.

The most important selenographers of this century, as LOHRMANN, MAEDLER and SCHMIDT, follow the principle introduced into astronomy by LOHRMANN himself, and which is taken from the manner of presenting terrestrial elevations brought into prominence by LEHMANN († 1811), a major in the Saxon army, and now universally used.

"According to this theory—to make use of LOHRMANN's own words—we suppose ourselves to be stationed vertically above each point of the section under observation, and to see all the mountain sides in their proper horizontal distances from each other, this being the only manner in which they can be accurately represented. The different ridges of the mountains will then have greater or lesser inclinations to the accepted vertical lines of sight, according to their relative steepness.

"Now, if we assume the mountains to be illuminated vertically, then the *horizontal* planes will reflect the most light, and the slanting

sides will reflect the faintest light. This difference in the illumination has, therefore, been recognized to be the natural manner of representing the mountains—in accordance with the truth—by the change from white to black. But as a mountain range can only be distinguished, as regards its position, when we know the direction of the slope as well as its steepness, we employ—in order to be able to meet both requirements in a satisfactory manner—black lines for the slopes, and draw the mountains by their aid, so that the lines always stand vertically to the horizontal contour lines with which we imagine the mountain to be covered. These vertical lines indicate by their position the direction, and by their thickness and proximity the steepness, of the slope."

LEHMANN, in making terrestrial maps, represented the horizontal plane as white and the inclined plane of 45° as completely black. In dealing with the moon, it became necessary to extend this scale to 90° on account of the great steepness of the lunar mountains, so that LOHRMANN represented the horizontal plane by white, the slant of 45° by half-dark, and the perpendicular precipice of 90° by black shading.

The charts of these three renowned selenographers are so well known that they require but brief mention. LOHRMANN conducted his observations in Dresden with a telescope of four and a-half inches diameter and a smaller one of three inches diameter. He made his first trials in measuring and drawing during the winter of 1821 and 1822. His continued observations for the production of a general chart of the moon having a diameter of three Paris feet (97.45 centimetres) in twenty-five sections, were commenced in the autumn of 1822.

Only four of these sections were published by LOHRMANN himself, on copper plates, in the year 1824, entitled "*Topographie der sichtbaren Mondoberflaeche, Erste Abtheilung*"; whereas the publication of the whole twenty-five sections—completed in 1878—took place long after his death (1840), under the editorship of SCHMIDT. LOHRMANN'S only other publication was a small map of the moon (diameter, 38.5 centimetres), in 1838, which was a lithographic print, showing, however, very rich detail, beautifully executed.

As already stated, the diameter of LOHRMANN'S large chart is three Paris feet—*i. e.*, one-half toise. Now, as the true diameter of the moon is equal to 468.4 geographical miles, or 1,783,200 toises, the former is 3,566,400 times larger than that of the chart, which

makes the scale of the latter 1 : 3,566,400. As a consequence, LOHRMANN's chart is on the scale:

$$1^{mm} = 3566.4 \text{ metres.}$$
$$= 0.48062 \text{ geogr. miles.}$$
$$= 1''.91374.$$

Although the drawing and engraving of this chart is most beautiful, it does not represent the principal characteristics of the crater formations quite correctly, inasmuch as it shows too broad summit rims; moreover, the gradations of light and dark shades of the surface of the moon are not correctly represented.

MAEDLER made his observations in Berlin, with BEER, the banker, at the private observatory of the latter, with a telescope of only three and a-half inches aperture. Their observations of the moon commenced in 1830, and were completed in 1836. Their chart was published in four sections, entitled "*Mappa Selenographica,*" in 1834–1836, by means of a lithographic reproduction, and had the same diameter as that of LOHRMANN.

Their next publication, issued in 1837, was the excellent and instructive work, entitled "*Der Mond, nach seinen kosmischen und individuellen Verhaeltnissen, oder allgemeine vergleichende Selenographie,*" and in 1838 a small chart of the moon, with a diameter of 32.5 centimetres (12.80 inches), was published, likewise by the aid of lithography. MAEDLER's large moon chart reproduces the individuality of the mountain formations beautifully, and is unequaled in detail and exactness, so far as the power of the instrument used by him permitted.

SCHMIDT is, with MAEDLER, one of the most thorough observers of the moon. He commenced his drawings of the moon in 1840, in his native city, Eutin, and continued them, during his whole life, at different places. In the year 1858 he commenced working in Athens, as director of the observatory of that city, with a telescope of six inches aperture; and this period may be regarded as the most successful time of his work in connection with the moon. SCHMIDT's general chart, completed in 1874, and reproduced from his original drawings by the heliotype process, has a diameter as large again (namely, 1.949 metres), as that of LOHRMANN, and is based on the position determinations of the latter. It shows an astonishing amount of detail, which requires no explanation, and the drawing of which is based on observations made during a period of no less than thirty-two years.

On this chart, the scale of which is 1 : 1,783,200, and which shows 32,856 separate ring mountain formations and 348 "rills," the relations are:

$$1^{mm} = 1783.2 \text{ metres.}$$
$$= 0.24031 \text{ geogr. miles.}$$
$$= 0''.97687.$$

Although this map does not give the correct impression of the differences in elevation as they actually appear on the moon, inasmuch as small ridges and veins are drawn much too prominently (so as to make the original map suited for the photographic reproduction of his drawing, which SCHMIDT contemplated making), and is inferior to the charts of MAEDLER and LOHRMANN as regards fineness, it is, nevertheless, a most trustworthy production, owing to its unusually rich detail, and is an example of untiring industry. This chart may be considered as presenting the limit of what a single observer can achieve during a short human life in this branch of astronomy, which unquestionably belongs to the most arduous in the science, and requires special adaptations on the part of the observer.

We may further mention the chart of NEISON, which is partly based on that of BEER and MAEDLER, and partly on numerous measurements made by himself, and which is very generally used, owing to its convenient size. This chart consists of twenty-two sections in octavo, which, connected, give a diameter of the moon of 61.0 centimetres (twenty-four inches). The relatively small scale of this map does not permit the character of the slopes of the mountains to be sufficiently shown, nor is any attention paid to the general shading of the moon; so that it is more of a map of reference than a true picture of the lunar surface. The accompanying textbook, however, entitled "*The Moon, and the Condition and Configuration of its Surface, 1876*," which states all that is known in regard to the surface of the moon in a very concise and clear manner, is of great importance, owing to the many new points of view which it presents. While the remarkable works which we have mentioned addressed themselves to the difficult ideal of representing the entire surface of the moon which is visible to us, other observers have confined themselves to special portions of the moon's disc, in order to be able to study and draw the details more carefully. In this connection, we must mention the exhaustive work of SCHROETER, the industrious observer of Lilienthal, near Bremen, which appeared in 1791 and 1802, in two volumes, entitled "*Selenotopographische Frag-*

mente zur genauen Kenntniss der Mondflaeche," and containing sixty-eight plates of special regions of the moon, observed with reflecting telescopes of four, seven, thirteen and twenty-seven feet in length, and with powers of one hundred and fifty to three hundred diameters. SCHROETER's object was, as he expresses himself, to represent a series of different portions of the moon with such truth and completeness, that in times to come a comparison of these drawings would show any changes which might have taken place on the moon. The plates, which indicate the shadows cast by the mountains and craters, show at once that SCHROETER was not an expert draughtsman, and that he tried to do more than his ability in this direction would permit. A truthful plastic effect is nowhere observable, and all the shadings are most arbitrary; in fact, the characters of all elevations, and especially the walls of the craters, are not truthfully represented; the latter, indeed, look like nothing but ordinary slopes. There is no question, however, but that an experienced selenographer can make even these charts serve a very useful purpose, by paying more attention to what they are intended to represent, than to the manner in which it is accomplished, and by referring to the accompanying text, which is based upon very thorough observations.

GRUITHUISEN's detail-drawings of the moon are much more natural; of these, forty-seven, made during the years of 1821 to 1827, were published by KLEIN in the seventh volume of "*Sirius*," reproduced by the aid of photo-lithography. Although KLEIN said, in 1879, that these drawings were the best and most complete which he had ever seen, and expressed his admiration of their truthfulness and fine execution, I cannot quite agree with him, as I am disposed to lay great stress upon the accuracy of scale in all such plastic drawings of the moon.

In recent years such detail-observations have had much attention, which was a move in the right direction, showing that the advancement of selenography depends, to a great extent, upon the continuation and careful additions to the results obtained by LOHRMANN, MAEDLER and SCHMIDT.

This fully confirms the introductory remarks which MAEDLER makes in his work, namely: Selenography will advance, as geography has advanced for centuries, and still advances, but with the difference that the latter rises from the local to the general, while the former pursues the contrary course.

Two methods have been employed in drawings of the moon—first, by representing the lunar features by means of conventional

signs; and, secondly, by giving truthful, plastic and picturesque representations of the different details.

Although the first method admits of a reproduction of the horizontal extension of the objects, as well as of their vertical elevation above the surface of the moon, it always requires a double interpretation, namely: that from the object to the conventional signs, for the observer, and that from these signs back to the object, for the reader. This must produce confusion and uncertainty, which drawbacks will be increased by the fact that this method is usually employed by draughtsmen of but little skill; and it is, therefore, by no means the best one for the production of a reliable document, to be used in the future. The second method only can be regarded as entirely trustworthy; it does not require interpretation by the reader, but reproduces the impressions of the eye with all the outlines, lights and shades; every one understands it, and every one can satisfy himself of its truthfulness to nature by a direct comparison. Naturally, a representation which is to compete with a photographic reproduction requires the greatest proficiency in drawing, and special practice in this branch; as plastic drawings, taken from the bird's-eye view—*i. e.*, such as will, by close attention to minute detail, show the elevations in the line of sight,—are the most difficult to produce.

I repeat that the greatest proficiency in drawing is necessary, not only on account of the endless variety of what is seen, but also on account of the rapid changes in color and shadows on the moon. Only the most trained eye, together with an unerring hand, will be able to produce the required truthfulness of the drawing. Unfortunately, this requirement is often overlooked, so that there is no lack of quantity, but a great one of quality.

I know some astronomers who draw objects in the heavens without ever having attempted to draw a terrestrial object from nature, and who, therefore, are far from possessing the ability to make correct representations. This is the reason why the illustrated parts of astronomical works generally appear to have been collected indiscriminately or to have been imperfectly reproduced, and as if more attention had been paid to their appearance than to their truthfulness. This is of particular importance in popular works, as the layman is not in a position to make observations personally, but must derive almost all his impressions of heavenly bodies from books.

But even that expertness in drawing which is universally considered as an accomplishment, and which generally amounts to but little, is entirely inadequate when drawings of the moon are in ques-

tion. I should feel like demanding of a competent draughtsman, that he not only should be able to make a truthful picture of a terrestrial landscape, but also that he should have proved his competence in the portraiture of persons, as the latter branch permits of no latitude for arbitrariness, which is not excluded in the drawing of landscapes, and consequently forms the best practice for learning to make an absolutely correct copy. He should also be proficient in drawing miniatures, as it is of importance, in dealing with the moon, to represent as much as possible in a small space. In this connection, we may consider the question, what scale the draughtsman of the moon should adopt. If the picture is to appear natural, it must not make very small or uncertain objects any larger or more distinct than they appear with the enlargement employed or under the momentary conditions of the atmosphere. Anything that, in reality, lies at the boundary of visibility, should only be indicated feebly in the picture. This principle is generally disregarded. Partly to give a free movement to the inexperienced hand, and partly to produce something prominent, some special regions of the moon are pictured too large and quite out of proportion, so that small craters and faint ridges are shown with great distinctness—as if these objects could be observed with the greatest ease; while, on the other hand, large plains of the picture are devoid of detail or show incomplete and incorrect shadings, which by no means coincide with the real formations of the moon's surface.

If we consider the magnifying power employed to be m, the corresponding angle under which the object appears in the objective may be called β. Now, if the angle at which the same object appears to the naked eye be α, we shall have, for objects that are not too much extended, the relation $\beta = m\,\alpha$.

The cone of rays which the eye receives from the eye-piece, with the object as a base, is now conceived by the draughtsman to be cut by the plane of his drawing.

The diameter l of this section gives the proper scale for the size of the drawing. If the distance between the drawing-paper and the eye be d, then $l = d \operatorname{tg} \beta$, and approximately $l = d\,\beta \sin 1''$, which gives $l = d\,.\,m\,.\,\alpha.\ \sin 1''$.

As an example, let us consider the mighty ring-mountain *Copernicus*, which has—according to MAEDLER—a diameter of 12.15 geogr. miles. As on the moon, at its mean distance, $1'' = 0.25114$ geogr. miles, it follows for the latter $\alpha = 48''.379$. Now, if we substitute for d the distance of distinct vision, 250 millimeters, and then

a smaller value, $d = 200$ millimeters, and also a variety of enlargements from 100 to 1000, we shall have the following table:

Magnifying Power.	Visual Distance = 250 m. m. Lineal Diameter l of *Copernicus.*	Visual Distance = 200 m. m. Lineal Diameter l of *Copernicus.*
	m. m.	m. m.
100	5.9	4.7
200	11.7	9.4
300	17.6	14.1
400	23.5	18.8
500	29.3	23.5
600	35.2	28.1
700	41.0	32.8
800	46.9	37.5
900	52.8	42.2
1000	58.6	46.9

Now, if we draw *Copernicus* with a diameter of six centimeters (with a distance of twenty-five centimeters from the paper to the eye), and only employ a magnifying power of twenty-five times, we have really taken the size corresponding to an enlargement of 1000 times, and the picture shows no more detail than if this crater had only been made the size of one centimeter. In the latter case, a good and conscientious draughtsman can execute the picture in a much more complete manner than in the former, so that for this reason, also, the advantage lies with the smaller scale. A selenographer who is proficient, from having drawn portraits and landscapes, will unconsciously choose the scales which we have mentioned, and will only allow himself to exceed them when the condition of the atmosphere is excellent and the detail is exceptionally rich.

As regards objects situated at the limit of visibility, their exact representation must be left to larger instruments, which are able to define *at once* that which the smaller instrument can only discern by laborious observation, and even then only incompletely.

The most pleasing pictures of the moon, as regards picturesqueness and plastic effect, were produced by NASMYTH and CARPENTER, in their work, "*The Moon, Considered as a Planet, a World and a*

Satellite," 1874. It is only to be regretted that their excellent pictures were not taken from nature direct, but consist of photographs of plastic models, which were executed from drawings, based on observations made during thirty years, mostly with a reflector of twenty inches. Even if the originals—which, unfortunately, were never published—had been of the greatest truthfulness, their conversion into relief would—owing to the captivating abundance of detail which is offered by the authors—produce untruths, which again lessen the value of these productions. Nevertheless, these pictures give us a better idea of the character of the scenery of the moon and its wonderful views than those of any other selenographer before that time. Among the best of similar drawings, we have TROUVELOT's fifteen pictures in the "*Annals of the Astronomical Observatory of Harvard College*," Vol. VIII, although they are not devoid of mannerism, and represent the formations somewhat as if they were made of dough.

Among the authors of the remaining numerous sketches of picturesque and plastic scenery of the moon, several have produced work of equal value, but the manner in which the results of their labors is reproduced generally leaves much to be desired.

As the work which had been done in this direction did not completely satisfy me, because it either did not consider half-tones at all, or at best only very carelessly, and therefore was lacking in plasticity and truthfulness, I came to the conclusion, in the year 1884, relying on my long practice in drawing and painting of every description, that I would devote a portion of my spare time, at the observatory at Prague, to plastic drawings of some portions of the moon.

I was actuated principally by the desire to reproduce the magnificent beauty of the landscapes of the moon as truthfully as possible. I further had the desire to lay a foundation for the solution of the question, in the future, regarding changes on the moon, by making truthful and complete drawings of regions close to the boundary of illumination, where the eye meets with great contrasts of light and shade. I chose the terminator, because it is the point at which photography encounters the greatest obstacles.

As the photographic plate, with a given time of exposure, will only be impressed by certain intensities of light, and the light parts will be over-exposed, while the dark ones are under-exposed, it cannot give a correct picture of such portions of the moon at sunrise or sunset, with their many gradations of tones from the brightest light to

the deepest black. On account of the different chemical and optical action of the rays of light, drawings will always have to supply what is lacking in photography. I was well aware of the difficulty of the undertaking, especially owing to the very unfavorable condition of observation at the observatory at Prague. This observatory is situated in the heart of a smoky town, lighted by gaslight, and is built in the shape of a tower, while the dome can neither be fully opened nor revolved. Observations have to be made through open doors, at a distance of thirty-eight metres above the ground. From March till August, 1884, I used a FRAUNHOFER telescope of three and one-half inches (97.6^{mm}) aperture and a power of 160, on an ordinary mounting. Later I employed a STEINHEIL instrument of six inches (162.6^{mm}) aperture, with powers of 139 and 152 diameters, on a parallactic mounting. While the former had always to be carried out on to the narrow balcony of the tower, the latter was permanently mounted just inside of the south door of the tower, and allowed observations near the meridian only.

The moon can only be followed for three hours with this instrument, so that my observations were limited to certain hours of the night, and also to a certain time. The most annoying circumstance is that the number of good nights is very small, on account of insufficient darkness of the sky, or on account of clouds, so that I am obliged to climb the high tower at all hours of the night. How often have I ascended the 126 steps of the tower, in the small hours of night, at a freezing temperature, to find, upon arriving at the top, that the atmosphere was too unfavorable for drawing, and that my task had to be left unfulfilled. How often the weather has seemed promising at the time the moon was on the meridian, so that a drawing has been commenced, until, suddenly, clouds have put a stop to the work and prevented the completion of the picture. In spite of all this, the pleasure of achievement and the thought of what was yet to be attained, have caused me to forget labor and loss of time, and I have been able to advance, slowly but surely. In using the telescope, I generally draw from one to, at most, two hours without intermission. As I generally employ the same magnifying power, the extent of the picture is only influenced by the amount of detail and the difficulties encountered in the portion to be represented. In case different enlargements are used, the portion of the moon which is chosen must naturally be smaller in proportion to the greater enlargement.

It is desirable to have a cloudless sky during the whole time of

drawing, so that intermissions shall not occur; for the completion of the picture should not be delayed, on account of the changes which take place in the shadows. Similar delays arise from the unsteadiness of the atmosphere; for whenever the object is continually seen indistinctly and obscured, the drawing becomes almost valueless. The first thing to do is to sketch the outlines and larger details of the landscape, as well as those of the shadows, and then to make comparisons to find any improvements which are needed. Then the shading is commenced, and it is desirable to avoid erasing, which should also be avoided in sketching the outlines.

The picture is entirely completed at the telescope, in pencil, so that no additions are required afterwards, as it undoubtedly seems better to represent a small area completely than subsequently to make drawings pleasing to the eye from mere sketches. Immediately, or as soon as possible after the observation, the drawing so obtained is gone over—during four or five hours—with the brush and india-ink, which naturally must be done with the greatest care and attention. Before commencing a drawing, I avoid looking at other representations or charts of the same region, so as not to be influenced by them in any way. It is owing to this circumstance that my drawings give a truthful picture of what a normal eye sees with the instrument and the enlargement employed in a given condition of the atmosphere. It is naturally a great advantage to prepare, in advance, for the drawing, the principal outlines of the object, either by the aid of suitable photographs, or by basing them on one's own previous drawings, in order to be able to devote all the time and attention at the telescope to the shading.

When I first began my drawings of the moon, the STEINHEIL telescope had no driving-clock, and had to be made to follow the moon by moving it by hand. In addition to this, my seat had to be shifted frequently, as well as the oil-lamp, which stood behind my head, the light of which was often insufficient. Furthermore, I had continually to re-sharpen my pencils, to be able to draw the finest details. Add to all this the exertion of reclining, for hours at a time, in an uncomfortable position, and sketching on a board supported only by one's hand, and the fingers becoming numb with cold in winter, and you will agree with me, when I say that all these drawbacks were not calculated to make these tedious labors appear in a pleasant light. Subsequently, however, it became much better. Since July, 1885, I have been in possession of a driving-clock of GRUBB'S construction; since September, 1886, I have had a convenient ladder

for observation, with reversible seats, and connected at the side of it was an adjustable table for a lamp, etc. Finally, in April, 1888, I obtained, in place of the oil-lamp, a small incandescent lamp, which is fastened to one's breast, and which always remains in the same relative position to the hand, and which can be lighted or extinguished at will.

The lead-pencils, of which there must be at least twelve different grades, are sharpened beforehand, and a fine file is kept in readiness to sharpen points that have become too dull.

Up to the present time (middle of April, 1890), I have obtained fifty-nine special drawings of craters and landscapes of the moon, situate at the boundary of illumination; of which forty of 1884, 1885, 1886 and 1887 have been published in the astronomical observations of Prague, by the heliographical process. (See the frontispiece.)

Although the heliogravure is by no means equal to the originals in luster and fineness, it, nevertheless, approaches them very closely, and is more to be recommended for such reproductions than photography. My trials in making reproductions in the ordinary lithographic manner also gave good results; but this requires that the engraver on stone should be a real artist, and that the impressions should be made in several tones.

Naturally, everything depends upon the excellence of the reproduction—for the student will blame the observer for anything and everything which is lacking in the published drawing. Even if my charts do not lead to the detection, in the future, of changes on the moon, they, nevertheless, present, I think, a truthful topographical addition to our knowledge of the moon's surface, and at the same time give an indication of what photography should endeavor to attain, as regards sharpness and clearness in pictures of the moon. Should my drawings only serve to stimulate the advance of photography, their object would be fulfilled.

The preceding remarks show that labors of this character can be executed with the most modest means, and it would be very gratifying if many observers, who possess the necessary proficiency in drawing, should cultivate the same field with perseverance. The value of the work does not depend so much on the quantity of the details obtained,—for as regards these the advantage will always lie with the larger instruments,—but on the *completeness* in the representation of what is seen, as parallel studies always form a welcome and valuable control, and as we are still far from having comprised the whole surface of the moon in such plastic drawings of its detail.

On the other hand, how interesting it would be to possess a number of such drawings of the same object for all phases of illumination through a whole lunation, or for the same phase in the different degrees of libration!

The principle should always be, to sketch only when the atmosphere is transparent and steady, and then to reproduce everything that is seen within the specified limits with absolute truthfulness. Particular attention will, therefore, have to be paid to the moon in high declinations, and in case the observations are made on the meridian,—which, of course, is the most favorable point,—we must consider the convenience of the draughtsman; and we must either construct the pier of the instrument sufficiently high, or lower the seat of the observer below the floor. Unfortunately, such arrangements cannot be made at Prague.

PRAGUE, April, 1890.

REFERENCES TO PROFESSOR WEINEK'S DRAWINGS OF THE MOON.

(SEE FRONTISPIECE.)

No. 1. Mare Crisium.
2. Sinus Iridium.
3. Theopilus, Cyrillus.
4. Gassendi.
5. Columbus, Magellan.
6. Tycho Brahe.
7. Fracastor.
8. Archimides.

ON THE AGE OF PERIODIC COMETS.

BY DANIEL KIRKWOOD, LL. D.

Are periodic comets permanent members of the solar system? Is their relation to the sun co-terminous with that of the planets, or has their origin been more recent, and are they, at least in many instances, liable to dissolution? A consideration of certain facts in connection with these questions will not be without interest.

In the brilliant discussions of LAGRANGE and LAPLACE, demonstrating the stability of the solar system, it was assumed (1), that the planets move in a perfect vacuum; and (2), that they are not subjected to disturbance from without. To these restrictions we may add (3), the implied condition that the analysis does not include all forms of